TRANSPARENT ARMOR OPTIONS GROUND VEHICLES

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Transparent Armor Types:

Glass Laminates

Plastic Laminates

Composite Laminates

(Next Generation)

Glass Laminates:

Usually of common soda-lime float glass layers of varying thickness, bonded together with PVB interlayers in an autoclave laminating process.

Advantages	Disadvantages
Common Technology	Thick, Heavy
Long History	Relatively narrow temperature performance range
Readily available	Lowest VLT & IRT
Relatively inexpensive	Glass Spalling

Plastic Laminates:

Acrylic and/or Polycarbonate layers, of varying thickness, bonded with compatible Interlayer materials in either an autoclave or cast laminating process.

Advantages	Disadvantages
Very Lightweight	Weatherability
Can be cut from sheets	Abrasion/Chemical resistance
Excellent impact resistance	BR resistance > Handgun levels
Good Spall Ply material	Relatively expensive

Composite Laminates:

Glass, Polycarbonate and/or Acrylic layers bonded together with compatible Interlayer materials in an autoclave laminating process (sometimes cast).

Advantages	Disadvantages
40 to 60% thinner & lighter than glass lams.	Longevity sensitive to design & process
Good thermal efficiency	Spall Ply abrasion/chemical resistance
All-weather performance	
Significant design latitude	
Excellent enhancement opportunity	
Highest BR capability	

Laminate comparison to defeat single-shot 7.62 NATO M80

	Composite Laminate	Glass Laminate	Plastic Laminate
			AIR SPACE
Relative Cost: (mat'ls only)	0.85 : 1	1 : 1	1.8 : 1
Weight:	26.2# / Sq. Ft.	13.25# / Sq. Ft.	14.14# / Sq. Ft.
Thickness:	1.250" (32mm)	2.235" (57mm)	2.383" (60.5mm)

Composite Vehicle Armor Concept:

7.62 NATO M61 AP

Semi-tempered Ultra Clear ITO Glass
S-123 Polyurethane interlayer
S-123 Polyurethane interlayer
S-123 Polyurethane interlayer (w/ TSE)
Semi-tempered Ultra Clear Glass
S-123 Polyurethane interlayer
Annealed Ultra Clear Glass
S-123 Polyurethane interlayer
Annealed Ultra Clear Glass
S-123 Polyurethane interlayer
Annealed Ultra Clear Glass
S-123 Polyurethane interlayer
Hardcoated Clear Polycarbonate

Examples of Composite Vehicle Armor in Service

Basic Threat
.22 cal., 17 gr. frag.

Supplemental Threat
.30 cal. 44 gr. frag.

“Up-Armor” Threat Level
7.62 NATO M80
3-Shots, 6” Triangle pattern

“Up-Armor” Threat Level
Extended Life Version
(Low-Spall)

Composite Armor Design Latitude:

6K lb. TNT @ 100’

.50 cal. FSP @ 8.5K FPS

20 mm FSP @ 4K FPS

447 gr. MK2 HE Hand Grenade @ 2’

Multi-impact 7.62 NATO M80 plus, 1 Hr. Physical Assault

Spall Ply Materials:

Key to the performance of Composite Armors, the Spall Shielding material must be compatible with the adjacent material, provide the required structural integrity, and include abrasion and chemical resistance.

		Tabor W/o HC	Tabor w/ HC
Polycarbonates:	Most ductile, best Spall Ply, poor chemical resistance	30	6 - 8
Acrylics:	Brittle, Fair chemical resistance	15	4 - 6
Polyester Films:	Thin (low threats), good chemical resistance	15 - 20	4
Laminated	Usually with PVB or Polyurethanes		
Adhesive	Solvent or water activated adhesives		
Cast Materials:	Soft, difficult to clean; still evolving	Varies	Varies
Thin Glass:	Brittle, excellent chem. / abrasion resistance	0.05	N/A

Spall Ply Concepts:

Standard Supplemental HMMWV

Hardcoated P/C Spall Ply

Thin Glass & Film added **Glass & separate P/C added** **Film added directly to P/C**

Abrasion/ Chemical Resistant Coatings (Hardcoat):

Used to protect (non-cast or glass) the Spall Ply materials from abrasion and chemical damage.

Standard types are Silicone or Melamine based ("wet chemistry") and are applied by flow coating, dip coating and spin coating techniques. They are thin and brittle.

Other Hardcoats under development include the Diamond-Like Coatings, Sol-gel ceramic coatings (The Welding Institute, UK), vacuum sputtered metal oxides, plasma applied ceramics and new or improved "wet chemistry" materials under development by Exatec LLC (a JV between Bayer AG and GE) and several others.

Important considerations include:

Performance requirement
Chemicals, including CW Agents
Armor design -vs- HC process
Armor configuration (flat, curved, size)
Subsequent processing
Expense

Armored Window Installation:

Historically, armored windows were of the small wedge shaped Vision Block type and simply wet sealed into a reciprocal shaped cavity in the vehicle hull.

Then came the bolt-on, preframed vision block assembly. Although this aided BDR installation, the vision block is wet sealed to the frame.

Now, several framing concepts exist, depending on vehicle type, of a more conventional style. Frames consist of a sub-frame and mounting ring. Windows use gaskets, with limited wet sealing, allowing faster BDR replacement with reusable frames.

Transparent Armor Threats:

While commercial passenger vehicles and money transport trucks continue to be primarily concerned with ballistic protection, today's Military Vehicle must also withstand a variety of non-impact threats.

Ballistic:	**Shrapnel (FSP), Bullets (Ball, AP & API)**
Blast:	**Shock & Overpressures**
Electronic:	**RFI / EMI, EMP / NEMP, Microwave, RCS (R)**
Optical:	**Heat Pulse, IR, Laser, Glint**
Environmental:	**Temperature extremes, CW Agents**
Maintenance:	**Operating environment, Cleaning, Replacement**

Transparent Armor Options & Enhancements:

The ability to laminate dissimilar materials offers significant latitude to incorporate multiple threat protections within a single window. Essentially any transparent material can be included to add its particular benefit.

Increased VLT, IRT (or, decreased IRT)

Electrical, transparent Heating for anti-fog / anti-ice all-weather vision

Electronic Shielding

RCSR (Reflective or Absorptive)

Upgrade & Retrofit opportunity

Gaskets / Framing systems

Next Generation Transparent Armor:

Although economic, transparent materials will continue to be glass, acrylics and polycarbonates for the foreseeable future, all of these will see improvements as their manufacturing state-of-the-art advances. Upcoming advances include co-extruded and fusion bonded materials, stronger and tougher interlayers and continued advancement in processing methods. These initial improvements will provide:

Harder, denser impact surface materials

Weather resistant AR (anti-glint) and rain repellent coatings

Holographic information displays and selective optical shutters

Electrochromics

Improved Spall Ply concepts and materials

Monolithic Armor

Transparent Armor Specifications:

The following partial list of the more common BR Standards not only points to the difference in perceived threat, but also are indicative of the escalating threat. Armored money trucks are no longer assaulted with the .38 cal. Handgun (old UL Level I) and "Mission Sensitive" Military Vehicles require compatible armors. A single specification requirements covering a single armor type is no longer valid.

	Witness Plate
Australian, AS-243	125g / sq. M Cartridge Paper
British, BSI-5051	115g / sq. M Cartridge Paper
Canadian, CSA 752	1/8" Cardboard
German, DIN 52290	Spall catch box
USA, ASTM F1233	0-temper 1mil Al foil
HPW-TP-0501	1mil Al foil
NIJ 0108.01	20mil 2024-T3/T4 Al sheet
UL 752	1/8" Cardboard

Most Military BR requirements today are Vehicle / Mission specific.
A few examples of vehicles with individual requirements are:

MLRS	RLST	XM-1114 & 6	LPD-17	PLS (Armor Kit)
HMMWV	LAV-AD	LHD	LCAC	5-Ton (Armor Kit)